THE TERRITORIAL BEHAVIOR OF PYRRHULOXIA (*Cardinalis sinuatus*) IN WEST-CENTRAL TEXAS WITH OBSERVATIONS OF BREEDING BIOLOGY

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ROGER RUSSELL WILKE

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by

ROGER RUSSELL WILKE

APPROVED:

[redacted]

Dr. Terry C. Maxwell, Chairperson

[redacted]

Dr. Edith C. Marsh

[redacted]

Dr. Ross C. Dawkins

[redacted]

Dr. Patrick M. Geoghegan

Date Successfully Defended and Approved by Advisory Committee

APPROVED:

[redacted] 5/8/95

Dr. Peggy L. Skaggs, Graduate Dean

[redacted]

Roger Russell Wilke

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INTRODUCTION

The Pyrrhuloxia (*Cardinalis sinuatus* Bonaparte) is a medium sized passerine (35.5 grams) in the family Emberizidae (Dunning 1993, A.O.U. 1983). This granivorous bird inhabits arid brush, thorn scrub, and thickets, especially mesquite (*Prosopis sp.*) (Anderson, in Bent 1968), and is very similar to the Northern Cardinal (*Cardinalis cardinalis*) in physiology, size, plumage, voice, and habitat usage (Gould 1961, Hinds and Calder 1973). The Pyrrhuloxia's distribution is limited to the southwestern United States and north-central Mexico. Its range includes south-central Texas west to southern New Mexico, southern Arizona and northern and central Mexico where it is also sympatric with the Northern Cardinal (A.O.U. 1983).

There are unanswered questions about the general life history of this species, particularly in Texas populations. The Pyrrhuloxia is a recent invader in Texas, New Mexico, and Arizona northward from Mexico following the increasing density of mesquite trees over the last 100 years (Oberholser 1974, Maxwell 1979). Knowledge of territoriality and breeding biology remain incomplete in the southern plains region of the Pyrrhuloxia range as it has expanded.

Limited studies in south Texas (Lemon and Herzog 1969)

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and southern Arizona (Gould 1961) are the only ones that have been performed and these are incomplete. Gould (1961) focused primarily on comparing Northern Cardinal and Pyrrhuloxia territories with limited observations of breeding biology. He found territories to remain fairly stable throughout the breeding season. However evidence exists (Yarrow 1970, Rich 1980, Conner et al. 1986, Moller 1990) that some bird territories are dynamic and not static. They change in size over the duration of the breeding season. Territory size also depends on the density and composition of the habitat (Odum and Kuenzler 1955, Hinde 1956, Potter 1972, Rich 1980). Lemon and Herzog (1969) focused primarily on song analysis and did not report a detailed study of territoriality or breeding biology. Anderson and Gross (in Bent 1968), describe the life history of the Pyrrhuloxia based mainly in part on Gould's (1961) study, and on a compilation of brief notes, and casual observations made in the early part of this century. Some features of Pyrrhuloxia breeding biology remain to be described: courtship display, pair bonding, nest construction, parental care, the number of broods per season, and brood parasitism by the Brown-headed Cowbird (*Molothrus ater*).

The purpose of this study was to examine and describe the natural history of Pyrrhuloxia during its reproductive season in West-central Texas with an emphasis on territoriality. In the territoriality investigation, I described territory

establishment, boundary and size, maintenance, defense, stability, and breakdown. Observations in breeding behavior included courtship display, pair bonds, nest location, eggs and incubation, parental care, nestlings, fledglings, and reproductive success. I also investigated food, foraging, and flocking behavior.

STUDY AREA AND METHODS

The study was conducted at a 16.4 ha brushland site near O.C. Fisher Reservoir, 0.8 kilometers North, 6.4 kilometers west of San Angelo, Tom Green County, Texas. The county is located between 31°05' and 31°42'N latitude and between 100°07' and 100°41 W longitude (Wiedenfeld and Flores, 1976). O.C. Fisher reservoir is currently property of the U.S. Army Corps of Engineers, from whom permission to conduct the study was obtained.

Vegetationally, the surrounding area is disturbed mesquite-mixed grassland varying from dense, brush thicket to moderately dense savannah. Predominant vegetation includes mesquite trees (*Prosopis glandulosa*), and associated brushy shrubs and trees, prickly pear cactus, (*Opuntia spp.*), and mid to short grasses (Maxwell 1979).

The study site has areas of both mature and immature mesquite trees with typical woody undergrowth. The mature mesquite is on the western edge of the study area and is accompanied with extremely dense undergrowth that includes white brush (*Aloysia gratissima*), tasajillo (*Opuntia spp.*), catclaw (*Acacia greggii*), and prickly pear cactus. The younger and more scattered mesquite trees with less undergrowth occur in the eastern part of the site. Several arroyos run through the area along with two usually dry stock tanks. Yearly rainfall data, obtained from the lake office

situated approximately two miles from the study site, indicated near normal (20.25 inches) annual values during the study period. Precipitation varied from 19.33 inches in 1993 to 27.72 inches in 1992.

To observe territorial and breeding behavior, individual birds were color banded. Narrow lanes were cut through the woody vegetation, so that nylon mist nets could be used to capture birds before the breeding season began. Federal and Texas permits for capturing and banding birds were obtained from the proper agencies. Each bird was banded with a unique combination of colored bands and with a standard U.S. Fish and Wildlife Service numbered aluminum band.

Individuals were intentionally captured only once, unless the need arose to replace lost bands. After the birds were banded, they were released in the area where they were captured. Individuals, color marked and identifiable, were observed with the naked eye, 8x40 binoculars, and a 20-40X spotting scope. Observations were made 4-5 times per week, weather permitting, from August 1993 through December 1994. Depending on the amount of daylight available, observations were made during peak activity periods in the morning (0600-1200) and in the evening (1700-2100) with intermittent visits made during the afternoon hours. Each bird was followed for at least an hour or until contact was lost.

Aerial photographs and maps of O.C. Fisher Reservoir were

used to develop a detailed map of the study area. This facilitated territory mapping, locations, and movements of individuals within the study area. Initially birds were observed over a period of several days until the location of favored singing perches and activity patterns were known (see Odum and Kuenzler 1955). When the general territory was known, boundaries were confirmed by noting the outermost limits where each bird sang (International Bird Census Comm. 1970) and by using Wein's (1969) "territory flush" procedure. Territory mapping continued throughout the breeding season to detect any variation. Territory size was determined using the cut and weigh technique (Lind 1979).

A percentage of dense woody vegetation coverage was determined for each territory by placing a grid over aerial photographs of the study site. The percentage was calculated by dividing the number of squares that contained vegetation by the total number of squares contained by the particular territory and multiplying by 100.

Breeding behavior was based on discrete observation of the birds and their activities. I also recorded the dates of particular events in the breeding cycle such as pair bond formation, nest building, egg laying, and development of young. Nest locations were plotted on the territorial maps. When feasible eggs and nests were collected, measured with calipers, and deposited in the Angelo State Natural History

Collections. Nests were examined during the breeding season using a broom handle with an angled mirror attached to one end. Nest height was measured with an extendable measuring rod. When possible I photographed nests, eggs, nestlings, and fledglings. Flocking and foraging was based on noting observations of these behaviors during the non-breeding and breeding seasons.

Spearman rank correlation was used to determine significant differences between territory size and vegetational density in this study and that which could be calculated from Gould (1961). A Student's t-test was performed to compare territory size observed in this study with that of Gould (1961). Simple regression analysis was used to determine if a change in vegetational density produced a change in territory size in this study and in Gould's (1961). All tests were performed using StatView™ (1992).

RESULTS

A total of 291 days and 1,746 hours was spent in the field from August 1993 through December 1994, with an average of 6 of hours per day. Capture and banding of Pyrrhuloxia in the winter of 1993-1994 proved to be difficult due to their seasonal flocking behavior. No birds were captured until establishment of territories by the males following the breakdown of winter flocks in late February 1994. Following onset of territory establishment on 20 February 1994, 20 individuals, 16 males and 4 females were captured and color banded. In the spring of 1994, seven of these males established territories averaging 1.47 ± 0.51 ha in the immediate study area. Six of these same males successfully pairbonded with a female. Only one banded female, P-13, established a pair bond with one of the seven banded males, P-3. Six active nests were found within the study area; three of these successfully fledged a total of six young. The other three were abandoned in mid breeding cycle, and no attempt at renesting was observed in these pairs. No evidence of parasitism by the Brown-headed Cowbird (*Molothrus ater*) was observed in any of the nests. During the season, Pyrrhuloxia became accustomed to my presence to the extent that I could approach them without altering their behaviors.

TERRITORIALITY

Male Pyrrhuloxias established and maintained type B

territories (Nice, 1941 and Hinde 1956) in which mating, and nesting, but not all feeding occurred. I observed males and females from different territories in an open communal feeding area outside the established territorial boundaries in late May, well into the breeding cycle. This behavior continued until the breakdown of territories in August. I defined territory following Gould (1961) as the area in which Pyrrhuloxias maintain and defend against other Pyrrhuloxias, and in which the birds nest, sing, breed, and raise young.

Establishment. In contrast from their winter tolerance of one another, upon the break-up of the winter flocks males became increasingly combative and aggressive toward each other. Territories were established with song, aggressive posture, physical contact, and aerial pursuits. By 20 February males were no longer seen in flocks and had begun to establish territories. A week later, 27 February, males were seen and heard singing from elevated perch sites. By 5 March aerial pursuits, aggressive posturing, and physical contact had been observed. By 18 March territorial boundaries were taking form. Territorial boundaries fluctuated from late February to the middle of April, but became firmly established during late April and early May. They remained fairly constant throughout the breeding cycle with only a few minor fluctuations during the early weeks of establishment and on the appearance of nestlings and fledglings. Females were not

observed defending a territory until after a pair bond was established. Then they occasionally aided the male in defending the territory against other Pyrrhuloxia pairs or nest intruders.

Singing was the behavior I observed the most in establishing territories. I noticed males singing in late February reaching a peak in mid May. I often had difficulty distinguishing Pyrrhuloxia songs from those of the Northern Cardinal. More often Pyrrhuloxia song phrasing was much shorter than that of the Northern Cardinal, but this was not always the case. Males would sing loudly from their perch sites, broadcasting from the highest points in their patrol route. Rival males would often sing back and forth to each other and duet singing was not uncommon. When a male would encroach upon or get close to another territory that was being established, he would sing aggressively with loud, repeated songs. The neighboring territory holder would answer back with the same song and the two would move toward each other, sometimes singing duets of the same call type. This singing often resulted in contact as neighboring males would approach each other.

Physical contact was limited to the early part of the breeding season from late February to mid April with the establishment of the territories. After establishment, contact and aerial pursuits were rare between established

neighbors after late May except when the occasional floater (unpaired male) would criss-cross territorial lines. When this happened, the intruder was promptly chased out of the owner's territory.

Defense. Pyrrhuloxias defend their territories only against other Pyrrhuloxias. Once territories were established by late May, they were maintained almost entirely by the males with song, patrolling, aggressive posturing, and to a lesser extent, aerial pursuits, and physical contact. In the males I observed, song and patrolling were used most often and in conjunction with each other.

I observed competitive singing between males of adjacent territories. Males would orient themselves on perch sites so that their voices would project away from their defended territories. Males would alternate songs of similar types and would occasionally sing duets. Territorial boundaries were seldom crossed in these singing bouts, although males did come to within 15m of each other regularly. Males would however, give the "chatter" call and posture aggressively. I did not observe competitive singing among males of non-adjacent territories. Female Pyrrhuloxias usually did not sing, but gave the typical "harsh chattering call" when making contact with a male or to signify alarm. I did witness one female that sang with the male when I approached their nest, but her song was quite subdued in both in volume and quality. Her

call resembled a forced tremolo compared with the strong smooth flowing calls of the male.

Males regularly patrolled their territorial boundaries. They would alight on a tree or bush, sing for a few minutes, and then continue on to the next in a regular pattern. Flight paths were straight and usually uninterrupted. All males used the same song perch sites consistently in their individual patrol routes within each of their territories. These remained consistent throughout the breeding cycle which also aided determination of territorial boundaries.

Most singing and patrolling occurred in the morning between 0630 and 1100 hours. Afternoons, were noticeably more quiet, especially during the summer heat with only occasional singing. Singing and patrolling increased at sunset (1800 h-2100 h), but never reached the peak of the morning hours. During an afternoon thunderstorm on 9 June, one Pyrrhuloxia could still be heard singing during the subsequent heavy rain. The rain lasted for 30 minutes after which many Pyrrhuloxias were heard singing. On windy days, with gusts to 25 m.p.h., Pyrrhuloxias sang seldom if at all. On one occasion, male P-17 sang for a few moments from the top of a mesquite tree, but had trouble maintaining his balance as the tree whipped him back and forth in the wind. After several futile attempts at singing, he flew to cover in the lower branches of some nearby mesquite trees.

When nestlings and fledglings were present, singing and patrolling by the male were concentrated in the immediate area of the nest. Outer territorial boundary limits were patrolled, but much less frequently.

Aggressive behavior was utilized only if neighboring Pyrrhuloxias crossed the boundaries of an established male or if a floater wandered into the territory. Disputes were generally observed at the boundaries between two adjacent territories and rarely in the center. An intruder would usually be met at the boundaries in which a chase, fight or often both would follow. In all cases the established resident male would force the intruder to leave. Contacts made within the territory always resulted in a chase until the intruder was forced to leave the territory.

When males did come into contact with one another, their crests would become erect, wings and tail would spread, body contour feathers would ruffle and or "puff out," while giving a "harsh chattering" call (Gould 1961). Pyrrhuloxias make this call when greeting members of the opposite sex, as an alarm, or in aggression. Males would chase each other in groups of three or more while giving the "chatter" call. On one occasion I observed two males that approached each other on a mesquite limb. With crests erect and contour feathers ruffled, they aggressively called back and forth. This continued for several minutes until one male suddenly flew

away with the other closely behind. An aerial chase ensued with the pair darting and diving until actual contact was made on one sally and they tumbled toward the ground. The two separated near the ground at the last possible moment and landed on different mesquite trees within 10 m of each other. After only a few seconds, the chase continued and I watched until they disappeared.

Floaters were more tolerated than established birds. More aggressive contacts were made between males of adjacent territories. These contacts nearly always resulted in loud "chipping" vocalizations, aerial pursuits, and often physical contact. On one occasion floater P-2 encroached upon a dominant established male, P-6. As soon as the dominant male spotted the floater and took flight after him. Male P-6 chased the floater until it had cleared his territorial boundary and then stopped pursuit. The floater was never seen in the area again. On another occasion, P-17, an established bird, landed on a consistently used perch site of an adjacent established neighbor, P-6. Pyrrhuloxia P-6, immediately flew halfway across his territory to engage P-17. The two engaged in combat, leapt up vertically in the air, and pecked at each other while making the "chattering" call. This occurred only briefly with P-17 retreating back to his own territory. I watched them engaged in this behavior four times during the course of the breeding cycle. In late April, I observed one

unbanded female and her mate P-1, defend their territory when another pair intruded. She and her mate P-1 were preening in a mesquite tree close to their territorial boundary, when another pair appeared approximately 30 meters away just inside the boundary. Male P-1, followed closely by his mate, chased the intruding pair out of their territory. They stopped chasing once the intruding pair cleared the territorial boundary. Both pairs gave the harsh "chattering" call while in flight.

Upon the arrival of nestlings, the amount of patrolling and singing was greatly reduced; however, more time was spent defending the actual area around the nest site while defense of the areas away from the nest was reduced. Females did not assist the male with defense except when the nest was directly disturbed by me. No other predators were observed disturbing the nests. Females would typically fly a short distance away and give the "harsh chattering" alarm call, while the male came to investigate. Males would either repeat the alarm call, or the two would also exchange "chipping" calls until I left the vicinity of the nest. On one occasion the female sang with the male when I approached their nest, but her call was quite subdued in both in volume and quality. Sometimes both parents would remain motionless in the distant (30 m) background. Although they exchanged chipping notes, they remained still. Other times they would move quickly from

branch to branch, sometimes within 10 m of me giving the loud "chipping" call. Only when I left the immediate vicinity of the nest and moved at least 50m away, would the female and sometimes the male return to the nest.

Composition and size. Seven Pyrrhuloxias established and maintained territories within the study area (Fig. 1). The shapes of the territories were irregular, varying from oval to elongate. There was no overlap of territorial boundaries and they were separated by no more than 10-15 m. The territories largely followed the major dense, woody vegetational lines from west to east around the base of limestone slope. All of the territories except P-11 were composed of a combination of open field and dense brush. The territorial boundaries remained stable throughout the breeding season with only minor fluctuations during establishment. With the arrival of nestlings and fledglings, territorial boundaries again fluctuated as males spent more time helping care for the young. More time was spent defending the area around the nest than on the periphery of the territory.

Territory size ranged from 0.63 to 2.08 ha with a mean of 1.47 ± 0.512 ha (Table 1). Territory occupied by dense brush ranged from 64.3 to 100%, with a mean brush percentage of 74.4 ± 15.7%. In Arizona (Gould 1961), the mean vegetational percentage based only on percent mesquite coverage was 43.3 ± 21.3%, with a range of 18 to 78%. The percentage of brush

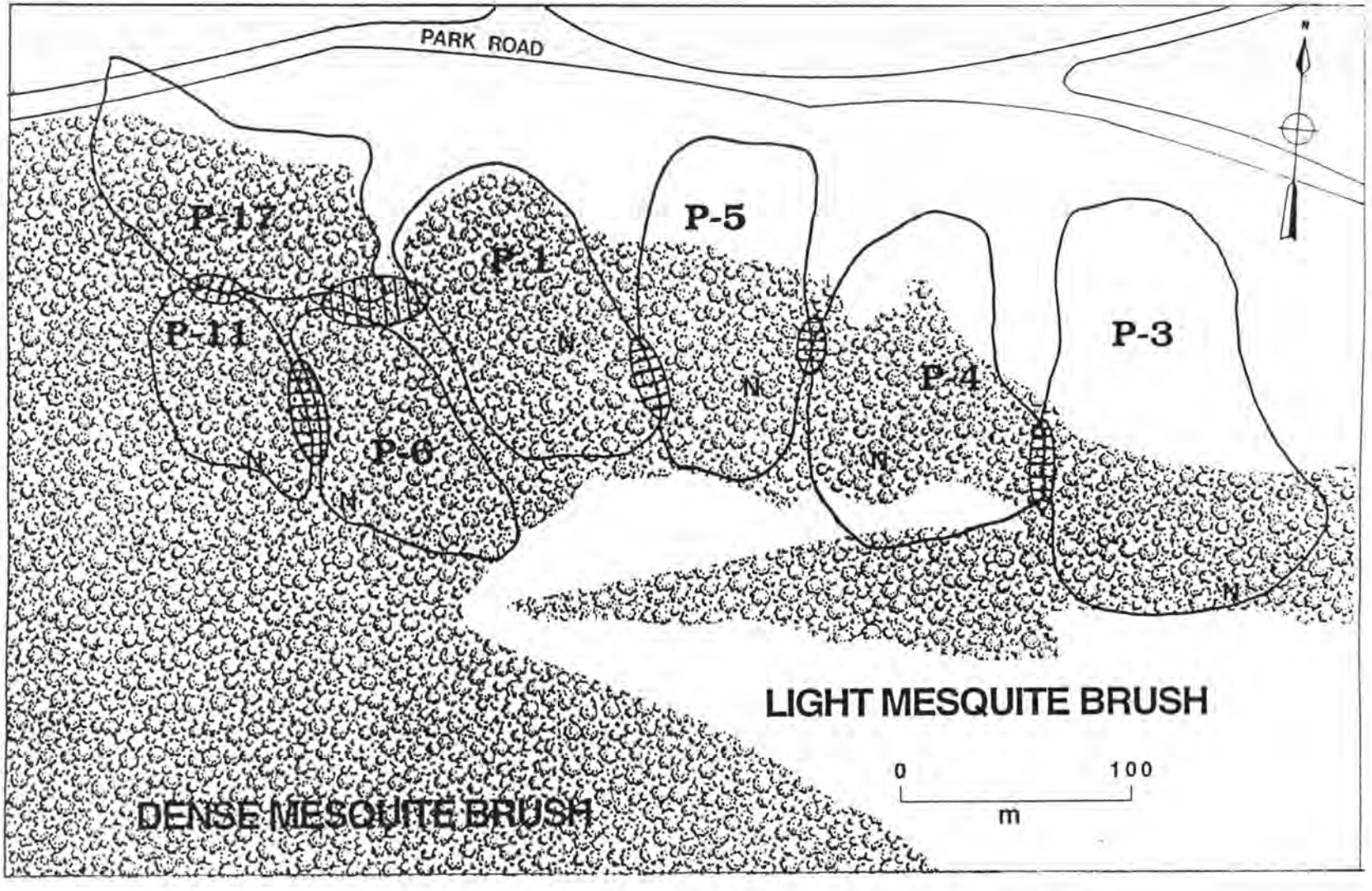

FIGURE 1. Distribution and boundaries of Pyrrhuloxia territories on the O. C. Fisher Reservoir study site in 1994. P- indicates territory, N indicates nest site, and cross-hatching indicates areas of interterritorial dispute.

TABLE 1. Territory sizes in hectares of Pyrrhuloxia on the O. C. Fisher Reservoir study site in 1994.

Pyrrhuloxia	Territory (ha)
1	1.61
3	2.08
4	1.84
5	1.71
6	0.94
11	0.63
17	1.46
MEAN	1.47
SD	0.51
CV	34.7

cover estimate indicates that in this Texas site, territories increased in size with decreasing brush density (Table 2). Territory size was significantly negatively correlated with vegetational density (Spearman rank correlation; $r=-0.807$; $p<0.05$, $n=7$). In Arizona (Gould 1961), territory size was not significantly correlated with mesquite brush density ($r=0.243$; $p>.05$, $n=7$). Territory size in Texas ($\bar{x}=1.47 \pm 0.51$) was larger than in Arizona ($\bar{x}=1.02 \pm 0.31$), and this was marginally significant by the Student's t-test ($p=0.07$).

A simple regression analysis revealed that brush density was significant in explaining 65.1% of the differences exhibited in territory size in this study ($p<0.05$; $R^2=0.651$) (Fig. 2). In the Arizona study (Gould 1961), simple regression analysis (Fig. 3) revealed that vegetation was not significant in explaining the differences in territory size and percent mesquite ($p>0.05$; $R^2=0.059$.)

Breakdown. Territorial defense began to degrade by 10 August. Degradation was characterized by reduced singing, patrolling, and physical contact between males. Once young were fledged from the nest, territorial defense was reduced. Males would aid the female in caring for the young and did not sing or patrol nearly as frequently as they had in the beginning of the breeding season. Subsequently, territory size decreased or was not maintained as frequently except for the immediate area around the nest. The males still sang and

TABLE 2. Territory size of Pyrrhuloxia in relation to brush density.

O. C. Fisher Reservoir, 1994			Pima County, AZ (Gould 1961)		
Bird	Territory (ha)	% Brush	Bird	Territory (ha)	% Brush*
11	0.63	100.0	2	0.53	27.0
6	0.94	82.0	6	0.89	54.0
17	1.46	63.6	7	0.89	18.0
1	1.61	88.6	10	0.93	78.0
5	1.71	64.3	3	1.17	25.0
4	1.84	62.0	5	1.34	52.0
3	2.08	60.5	4	1.42	50.0
MEAN	1.47	74.4	MEAN	1.02	43.43
SD	0.51	15.7	SD	0.31	21.13
CV	34.69	21.1	CV	30.39	48.7

* Mesquite density only.

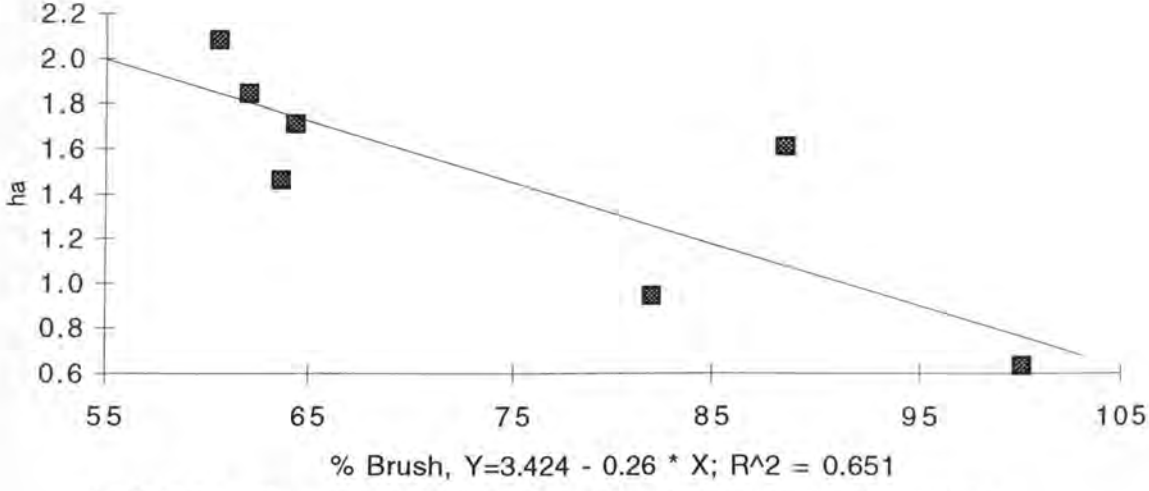

FIGURE 2. Regression analysis of territory size in relation to percent brush for Pyrrhuloxia on the O. C. Fisher Reservoir study site in 1994.

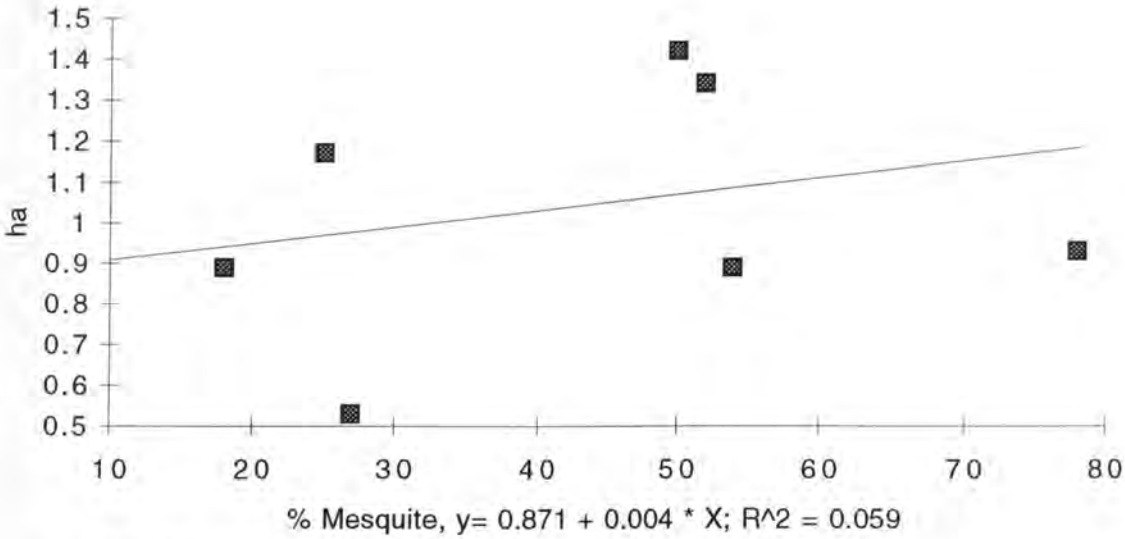

FIGURE 3. Regression analysis of territory size in relation to percent mesquite for Pyrrhuloxia in Arizona (Gould 1961).

patrolled this area frequently until the young were abandoned by both the parents. By 1 September, no defense of any kind was observed. With the breakdown of territories, flock formation began. Flocks of juveniles (5 plus individuals/ flock) began forming near the beginning of July. A flock of three males, five males, and six juveniles was observed on 27 August. A summary of territory phenology is given in Table 3.

PAIR BONDS

Males arrived at the study site in late February, earlier than the females which were still in small flocks when males began establishing territories. In late March the arrival of a female into a preliminary territory, would elicit responses from several males from adjacent territories. The harsh chattering calls made by the male who first discovered the female would attract other nearby males.

On 25 March, I saw three males approach a female that did not respond to their advances. The female was silently preening herself, just inside male P-4's territory and was approached by him first. He approached giving the "harsh chattering" call and was quickly joined by two other males with adjacent territories, males P-5 and P-3. Males P-4 and P-5 perched on the same mesquite branch with the female while P-3 perched below her. All of the males gave their harsh chattering call with a visual display of crests erect, wings spread downward, and tail spread in fan-like manner. The two

TABLE 3. Territory phenology of Pyrrhuloxia.

Event	Dates (1994)
Breakdown of winter flocks	20 February-27 February
Males singing	27 February
Aggressive behavior	5 March
Territorial boundaries established	20 April-10 May
Breakdown of territories	5 August-20 August
Establishment of winter flocks	9 July- 1 November

on the branch both moved closer to the female continuing these behaviors. The one below the female did not move, but continued to call and display . The female continued preening until the two males on the branch were right next to her. At this point the female flew away followed closely by all three males who made a "fluttering" sound with their wings as they flew after her. The males chased her through the brush and continued to call. I observed them until I lost sight. The female was not banded, so I do not know if these males were successful in their attempt to obtain this particular female as a mate.

I observed one male encounter a female without any other males present on five occasions during late March to early April. If a solitary male encountered a female, he would fly up to her making the "fluttering" sound with his wings while vocalizing, "the harsh chatter call". When the female did not respond to the call, a chase would soon follow, and I would watch until they vanished from view.

I observed the "harsh chattering" call returned by the females on six occasions and each behavior was consistent each time. Instead of immediately flying away, these females would imitate the males' chattering call. On spotting the female in his territory, the male would call, fly to where the female was perched, and sit approximately 10 cm away. The male and the female would continue to call back and forth, while the

male would display with his crest erect, wings spread downward, and tail spread in a fan. He would bow his head, turn upward to look at the female, and then rise up again. He repeated this bowing movement three or four times. Females would continue to respond to the call, but did not perform any courtship display. The male would continue this behavior for two to three minutes, until the female flew away to a nearby branch (10m). The male would then give chase making the "fluttering" sound and again perch next to her. This routine would continue until I lost sight of them.

By late April, flocks of females were no longer seen, but a single female would be found in association with a male on his territory. I did not witness any courtship feeding during this time as reported by Anderson (in Bent, 1968). Males and females would travel together often following one another if one or the other flew from a perch site first. I also observed them foraging side by side in an open area exchanging soft chipping calls. Although I witnessed no copulations, the Pyrrhuloxias were assumed to be monogamous because of the males' territorial defense. Six of the seven Pyrrhuloxia males that established territories within the study site were able to establish a pair bond. Bird P-17 was unpaired. In only one case where a pair bond was established were both sexes banded, male P-3 and female P-13.

NESTING

Phenology. I discovered six nests in the study site at various stages of development. Table 4 summarizes the breeding phenology of the Pyrrhuloxia. Nesting began in mid May and ended during the third week in August 1994. Eggs were estimated to have been laid from late May to late July. Hatching dates were estimated to be from as early as mid June to as late as late July. Fledging dates were from late June to mid August.

Nests. I was unable to observe construction of the nests although, I did observe two females carrying nest building material on 15 May and 3 June. I did not observe any males constructing nests or carrying building material. Nest building was estimated to have taken place in May through July. Nests were constructed entirely of dead material consisting mostly of grasses and twigs. Rootlets, spider webs, and feathers were used to line the nests. Table 5 describes the characteristics of six Pyrrhuloxia nests found on the study site. All were cup-shaped ovals with average outside diameters of 10.7cm x 8.8cm ± 0.78 x 0.55, and outside depths of 5.9cm ± 0.85. The average distance from the ground of the nests was 3.40 m ± 0.737, range 2.76 - 4.80m (Table 5).

All the nests were placed in mesquite (*Prosopis glandulosa*) and were not anchored to the tree in any way. All were placed on outer forks in the upper third of the tree in

TABLE 4. Breeding Phenology of Pyrrhuloxia.*

Event	Dates (1994)
Males singing	20 February-27 February
Pair bonding	25 March-30 April
Initiation of nest building	15 May-3 June
Clutch initiation	31 May-25 July
Hatching	15 June-31 July
Fledging	30 Jun-23 August

* Data based on observations from 6 pairs

TABLE 5. Characteristics of 6 Pyrrhuloxia nests.

NEST	OUTSIDE DEPTH *	INSIDE DEPTH *	OUTSIDE DIAMETER (LENGTH X WIDTH)*	INSIDE DIAMETER (LENGTH X WIDTH)*	WALL THICKNESS *	WEIGHT (in grams)	DISTANCE FROM GROUND (meters)
1	7.1	4.2	11.8 x 9.2	8.9 x 6.2	1.6	19.1	3.24
2	5.4	4.2	11.3 x 8.2	6.7 x 5.6	1.7	10.2	2.76
3	6.5	4.3	10.0 x 9.4	7.5 x 6.0	1.5	13.1	4.80
4	4.7	2.0	10.4 x 8.9	6.4 x 5.2	1.7	9.1	3.47
5	5.6	3.1	10.0 x 8.1	7.3 x 5.9	1.7	11.7	3.13
6	5.9	3.7	10.7 x 9.2	8.1 x 6.9	1.5	10.8	2.90
MEAN	5.9	3.6	10.7 x 8.8	7.5 x 6.0	1.6	12.3	3.40
SD	0.8	0.9	0.78 x 0.55	0.92 x 0.58	0.1	3.6	0.74
CV	13.6	25.0	7.29 x6.25	12.3 x 9.7	6.3	29.3	21.8

*Measurements in centimeters.
All nests placed in mesquite (*Prosopis glandulosa*).

branches that were protected on the west side by overhanging branches. Nests were placed in different locations within the territories (Fig. 1), but I did notice that each was oriented on the north, north-east, or south side of the mesquite in which they were placed. I did not observe any nests placed on the west side of mesquite trees.

Eggs and Incubation. I did not take measurements of eggs. The eggs of Pyrrhuloxia were oval, bluish white, and dotted with irregular brown splotches. Eggs may be laid any time between May and late July. Table 4 lists the nesting records for the 1994 breeding season. Nest 1 contained one egg which was later abandoned on 1 July. Nest 2 contained four eggs which were abandoned on 15 July. I discovered that the eggs in this nest were infested with ants and maggots after it was abandoned. Nest 4 contained three eggs which were abandoned on 21 July. Nest's 3, 5, and 6 were discovered with nestlings.

I observed only the females incubating the eggs. Females would sit on the nest 45 minutes at a time before leaving for as little as 10 minutes or as long as 55 minutes. I observed male P-6 feed his unmarked female while she was on the nest. He would approach giving a soft "chipping" call which the female would return. He perched on the wall of the nest and fed her. I was unable to detect the source of the food or its' identity. I observed this behavior on two separate occasions

while watching the nest, 3 August and 6 August. No other pair was observed to perform this behavior.

Nestlings. I discovered nestlings in nests 3, 5, and 6 on 2 August, 11 August, and 16 August respectively. Nest 3 contained only one nestling, Nest 5 contained three nestlings, and Nest 6 contained two nestlings. The nestlings of every nest had pin feathers already in development. Nestlings were grayish, brown, with bright yellow bills, and a bright red mouth.

I observed mostly the females attending the young, but males did contribute on occasion. The females made more trips per hour (5) than did the males (2). When nestlings were present, both parents foraged in the denser areas of woody vegetation in their territories and on the ground. During the early part of the season before nestlings were present, brief excursions were made outside of the territory to common feeding sites in the areas of light mesquite brush density. When the birds were feeding in these areas, I observed no aggessive behavior between pairs or individuals. In early May, I observed three pairs of adults (one banded pair, two unbanded pairs) feeding in a grassy open area well outside any of their established territories. However once nestlings were present, I did not observe them in that area again.

I observed both females and males gleaning insects from trees and shrubs. They would move up the main trunk of a

mesquite searching methodically for insects. When they caught an insect, they would either eat it whole immediately, or return to the nest with the insect in their bill back to the nest. Pyrrhuloxia were observed to catch various types of grasshoppers, katydids, caterpillars, and even some beetles. When the birds would forage on the ground, it was difficult to determine what type of food they were consuming. Pyrrhuloxias were observed consuming the fleshy fruits of prickly pear cactus (*Oppuntia spp.*).

I witnessed male P-6's unbanded female sally for flying insects on two separate occasions, 29 July and 5 August. The first occurred after she had finished feeding her nestling. She had perched on a branch approximately 3m from the nest at the top of a mesquite tree (4.8m). When a large unknown wasp sized insect flew by, she flew toward it, caught the insect, and returned to her original perch site where she ate it. After consuming the insect she flew from her perch site toward some dense whitebrush, and I lost visual contact. The second occasion was similar to the first, but she was perched on a different limb of the same mesquite tree. This limb was approximately 1.5 m from the ground. She had just finished feeding her nestling, and was preening herself. A smaller fly sized insect was flying above and to her right. She left the branch, performed a near loop in the air, and returned to the original perch site where she again ate the insect. After

doing so she left the branch and flew to the same patch of whitebrush mentioned above.

The chicks produced soft peeping sounds at the arrival of either parent and stretched their necks upward, mouth agape to receive food from their parents. The food consisted of insects carried in the bill. I did not observe any regurgitation feeding. Female P-13's bill was brightly stained reddish pink from consuming prickly pear cactus fruits, and she could have been feeding this to her young as well. Female P-13 would return every 15 minutes to the nest with an insect carried in her mouth. She was seemingly unconcerned with my presence approximately 10 m away. Her mate P-3 would return to the nest every 30 minutes for a few seconds and then disappear. An unmarked female in P-6 territory would leave the nest for longer periods of time and return very warily, watching me and producing the chattering alarm call. After 13 August she was no longer seen feeding the nestling. P-6 assumed the responsibility. His territorial defense was almost nonexistent. He would only occasionally sing in the immediate vicinity of the nest. When I approached the nest, he would give his alarm call or sing very loudly. I noticed no other Pyrrhuloxias encroach on his territory at this time which was late in the breeding season. When I approached the nest to investigate, the nestlings would huddle down below the rim of the nest and remain motionless

and silent.

Fledglings. The nestling in nest 3 fledged on 12 August. The three nestlings in nest 5 fledged on 13 August. The two nestlings in nest 6 flew out of the nest at the sight of my mirror on 21 August. In all cases the fledglings were only able to fly short distances (approximately 2m) from tree to tree and hop very clumsily from branch to branch. Flight feathers were not fully developed and their tails were short and stubby. The fledglings were covered in grayish brown plumage with no other noticeable coloration. Bills were dark gray almost black.

In cases where there was more than one fledgling, they would follow each other in the branches and sit next to each other. When a parent arrived, they would give soft peeping calls and have there mouths wide open to be fed. I observed 3 more mature juveniles following a mature female as she flew from mesquite to mesquite. They would follow her giving the harsh chattering call, but the female was not responsive to their calls.

The solitary fledgling from nest 3 continued to be cared for by male P-6. I was unable to relocate any of the fledglings or the parents after studying them for one day after they had left the nest.

I observed three juveniles in a flock on 1 July with no adults accompanying them. They were the same size as the

adults, but their plumage was still brownish gray. Their bills were the same parrot-like shape of the mature adult; however, juvenile bill coloration was dark brown in contrast to bright yellow of the adults. Juveniles were heard giving the "harsh chattering" and "chipping" calls to each other, but I did not hear any of them sing. Juveniles were seen foraging together in open grassy areas of the study site.

Reproductive outcome. Table 6 summarizes the reproductive outcomes of Pyrrhuloxia observed at my study site during the 1994 breeding season. Three nests were abandoned in July and I noticed no attempt at renesting. The other three successfully fledged a total of six young for a 2.0 fledglings/male ratio. Three of the six pairs were unsuccessful in fledging any young as the nests were abandoned and no attempt at renesting was observed. A total of eight eggs was abandoned, none of which hatched. No parasitism by the Brown-headed cowbird (*Molothrus ater*) was observed, although they were present at the study site.

FLOCKING BEHAVIOR

Flock formation of fledglings began soon after they were abandoned by their parents during the latter part of July and early August. Groups of up to six juvenile Pyrrhuloxia were seen traveling and foraging together crossing over many territorial boundaries as early as 9 July. Territory owners did not defend against these juvenile flocks. By late

TABLE 6. Outcome of nesting attempts by Pyrrhuloxia.

Sample/Outcome	1994
Pairs under observation *	6
Nesting attempts monitored ^	6
At least one fledgling	3 (50%)
Total number of fledglings	6
Nests abandoned	3
Eggs abandoned	8
Renesting attempts	0

*All Breeding paris for which some reproductive data were gathered.
^The total number of nesting attempts for which outcome was determined.

September, I saw flocks ranging in size from 5 to 15 individuals including adults of both sexes. These groups would forage together mainly in the open more grassy areas inside and outside the study site. By November and December the flocks reached their greatest density. I observed flocks with combinations of males, females, and juveniles ranging in size from six individuals to more than 30 individuals in an open field adjacent to the study site.

Many of the larger flocks (between 15 and 30 individuals) that I saw were feeding along the mowed grassy sides of the park roads at O.C. Fisher Reservoir. Pyrrhuloxia were seen feeding along with various sparrows species, Northern Cardinals, and Lark Buntings (*Calamospiza melanocorys*). These flocks were relatively fearless allowing me to come within 15m, sometimes ignoring my shouts and even my car horn. They foraged on the ground on grassy stems, seeds, and other unknown material while making the "soft chipping" call to each other. When disturbed, usually by me getting closer than 15 m, the birds would all take flight, giving their "harsh chattering" call, in the same direction heading for the cover of dense brush. They would not return until I had move 30 or more meters away. Some of these larger flocks near my study site contained individuals that I had banded 9 months previously, but were not included in my territorial study. All were males (P-9, P-10, P-12, P-14, P-15, P-18) except P-

12, a female. Only two individual territory holders in my study site were seen traveling within a flock after conclusion of the breeding season, P-3 and P-17. I was unable to follow the movements of these flocks during the winter months, but periodically observed them when the opportunity presented itself.

DISCUSSION

In the spring of 1994, seven male Pyrrhuloxias established type B territories averaging 1.47 ± 0.51 ha in the immediate study area. Territory size was significantly negatively correlated with vegetational density. Simple regression analysis revealed that 65.1% of Pyrrhuloxia territory size is due to brush density.

Six males successfully pairbonded with six females. I discovered six active nests within the study area; three of the nests successfully fledged a total of six juveniles. The other three were abandoned in mid breeding cycle, and no attempt at renesting was observed in those pairs. Even though Brown-headed Cowbirds (*Molothrus ater*) were seen in the study area, no evidence of parasitism was observed in any of the nests.

Published studies on Pyrrhuloxia territoriality and breeding biology remain vague and incomplete. They are limited to various notes, anecdotes, and casual observations performed around the turn of the century and in the early 1920's and 30's. Most of these are compiled by Anderson and Gross (in Bent, 1968). These authors relied almost totally on these incomplete accounts and Gould's (1961) Arizona study to describe the territorial and breeding behavior of the Pyrrhuloxia. The only accounts on these behaviors are two studies conducted almost 25 years ago (Gould 1961, and Lemon

and Herzog, 1969).

Territorial function is highly disputed in the literature, but most agree that it is flexible and highly dynamic (Hinde 1956, Brown 1969, Verner 1977, Arcese 1989, Moller 1990). Pyrrhuloxias at the O. C. Fisher Reservoir site maintained and defended territories against other Pyrrhuloxias in which singing, mating, nesting, but not all feeding occurred, a behavior consistent with type B territory as defined by Nice (1941) and Hinde (1956). Gould (1961) also noted that Pyrrhuloxias in Arizona made brief excursions outside of their territories for food and water. This is interesting because it suggests that if birds are leaving territories to acquire food and water, territories may not be selected on the basis of food acquisition alone, but rather other factors such as nest placement, density of competitors, pairbond formation, or to ensure an adequate supply of food for young (see Hinde 1956). Simple solutions for territory functions are unlikely to be found (Wasserman 1980).

Gould (1961) found that singing and intraspecific aggressiveness began in late February and March in Arizona, a timing consistent with the species in this study in Texas. However, Pyrrhuloxias at the O. C. Fisher Reservoir site established territories sooner than did those in Arizona (Gould 1961). In this study, territory boundaries began to take form on 18 March as opposed to late April and early May

in Arizona. Lemon and Herzog (1969) did not report dates of territory establishment in South Texas.

Male Pyrrhuloxias in this study maintained their established territories primarily with song, a result consistent with the findings of Gould (1961) and Lemon and Herzog (1969). Territorial defense in Arizona and South Texas also involved regular patrol routes, straight flight paths, and consistently used perch sites. These defense behaviors may allow the male to minimize time and energy spent defending the territory. Less energy is used to search for perch sites, and flight energy may be saved by following a regular patrol route.

There is evidence to suggest in other species that territory size changes when nestlings and fledglings are present (Hinde 1956, Yarrow 1970, Moller 1990). In this study, male Pyrrhuloxias used more time defending the immediate area around the nest when nestlings and fledglings were present, and only reduced their frequency of defense on the territory periphery.

Although most aspects of territorial behavior (establishment, defense, end-of-season breakdown) of Pyrrhuloxia are similar among this study site in Texas, South Texas (Lemon and Herzog 1969), and Arizona (Gould 1961), territory size varies noticeably among the sites. Territory size in this study ($\bar{x}$= 1.46 $\pm$ 0.51 ha) was within the range

(0.6 - 8 ha) reported for the species in previous studies, and was similar to values found by Gould (1961) in Arizona, ($\bar{x}$ = 1.02 ± 0.31 ha) and Lemon and Herzog (1969) at Falcon State Park in Texas (0.6 to 1.0 ha). Average territory size at the Welder Wildlife Refuge in Texas (Lemon and Herzog 1969) was markedly greater (> 8 ha), but may have reflected a poorer quality habitat described as open mesquite-buffalo grass. Territory detail, useful for comparison to this study, is most complete for Gould's (1961) study in Arizona. In Arizona, the smaller average territory size (1.02 ± 0.31 ha) was associated with a larger population (84 banded birds on 17 ha) than found on O. C. Fisher Reservoir (20 banded birds on 16.4 ha). Territory size at the Welder Wildlife Refuge (Lemon and Herzog 1969) was larger, and only four pairs occupied a site of 16 ha. The apparent relationship between smaller territory size and larger population supports Brown's (1969) hypothesis that smaller territories allow all of the population to fit into the available space.

One factor associated with territory size on the O. C. Fisher Reservoir study site was different from the Arizona study site (Gould 1961). In the Texas study, brush density was significantly negatively correlated with territory size. As brush density decreased, territory size increased. In Arizona (Gould 1961), mesquite density was not significantly correlated, in either direction, with territory size. Whether

population size or amount of brush coverage has the greater influence on territory size remains to be determined for this species.

Most nesting behaviors (nest construction, nest material, nest shape, nest measurements, and nest height) of the O. C. Fisher Reservoir Pyrrhuloxias were not notably different from that previously reported by Gould (1961) and Anderson (in Bent 1968). Although sample size was small, all Pyrrhuloxias in this study placed their nests in mesquite trees. Other accounts (Gould 1961, Anderson in Bent 1968) reported a preference for mesquite but some utilization of other brush species.

Clutch size, incubation time, and parental nesting behavior were not different from previous accounts (Gould 1961, Anderson in Bent 1968). Nestling period has been reported to be 10 days (Anderson in Bent 1968), but in nest 3 in this study, the one nestling remained more than 11 days. Previous accounts of parental care (Gould 1961, Anderson in Bent 1968) note simply that both parents care for the young, but in this study, females were more involved (5 visits/hour) than were males (2 visits/hour).

CONCLUSION

This study found that Pyrrhuloxias in the southern plains part of their range behave much like those in other areas with the exception of breeding and territory phenology, and territory size. Pyrrhuloxias establish and defend type B (Nice 1941, Hinde 1956) territories with song and aggressive behavior beginning in late February and terminating in late August. Territory size remains stable except when young are present, and then the frequency with which they are patrolled is reduced. Territory size is significantly negatively correlated with mesquite brush density.

The breeding season begins with the establishment of pair bonds in late March to late April and ends with the fledging of young in late August. Nests are placed in the upper branches of mesquite and shielded on the west side by leaves. Clutch sizes range from 1-4 eggs, and incubation lasts 14 days. The time the young are in the nest lasts more than 11 days. Females are the primary care givers of the young. Upon fledging the young are capable of short sustained flight. Juveniles form flocks which move independently across territorial lines and are joined by mature adults at the termination of the breeding season. No evidence of Brown-headed Cowbird parasitism was observed. Whether or not Pyrrhuloxias produce more than one clutch per season is still unclear.

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